DEPOSITIONAL ENVIRONMENT
OF THE GREEN RIVER FORMATION
NEAR AXTELL, UTAH

A Thesis

Presented in Partial Fulfillment of the Requirements
for the Degree of Bachelor of Science

by

Steve A. Hash

The Ohio State University

1981

Approved by

Adviser
Department of Geology
and Mineralogy

Table of Contents

List of Figures

Acknowledgments

I wish to acknowledge the helpful comments and criticism of my Adviser, Dr. K.O. Stanley. In addition, I wish to thank Dr. Gunter Faure for the use of his X-ray defractometer.

Introduction

The Colton and Green River Formations of central Utah have long been known to represent marginal-lacustrine and lacustrine deposition in Eocene Lake Unita. Lake Unita occupied the Unita structural basin and extended southwestward along the trend of the Sevier thrust belt into central Utah, including the Wasatch Platèau-Gunnison Plateau region of this study (Figure 1). The stratigraphic sections studied for this report are located along Willow Creek near the town of Axtell, Utah, in the Redmond Quadrangle (Figure 2). The out-crops present in this area consist of folded Jurrasic Arapien shale overlain unconformably by the Flagstaff, Colton, or Green River Formations. The Flagstaff, Colton and Green River Formations represent differing stages of the lake. The presence and absence of oil shale in the Lake Unita deposits is a concern of the petroleum geologist. The relationship of the sedimentary facies from these formations along with their depositional features and mineralogy will help interpret the depositional history of these stratigraphic sections. From these interpretations it will be drawn as to why oil shale is lacking in this area of Lake Unita.

Geologic Setting

Two stratigraphic sections were measured and samples collected north of Willow Creek on the two north-south trending ridges, one Flagstaff and Colton and the other Green River. These ridges are located on the western base of the Wasatch Plateau. The Wasatch Plateau is the western margin of the Colorado Plateau, which borders the

Figure 1--Generalized location of study area with respect to local geologic structures.

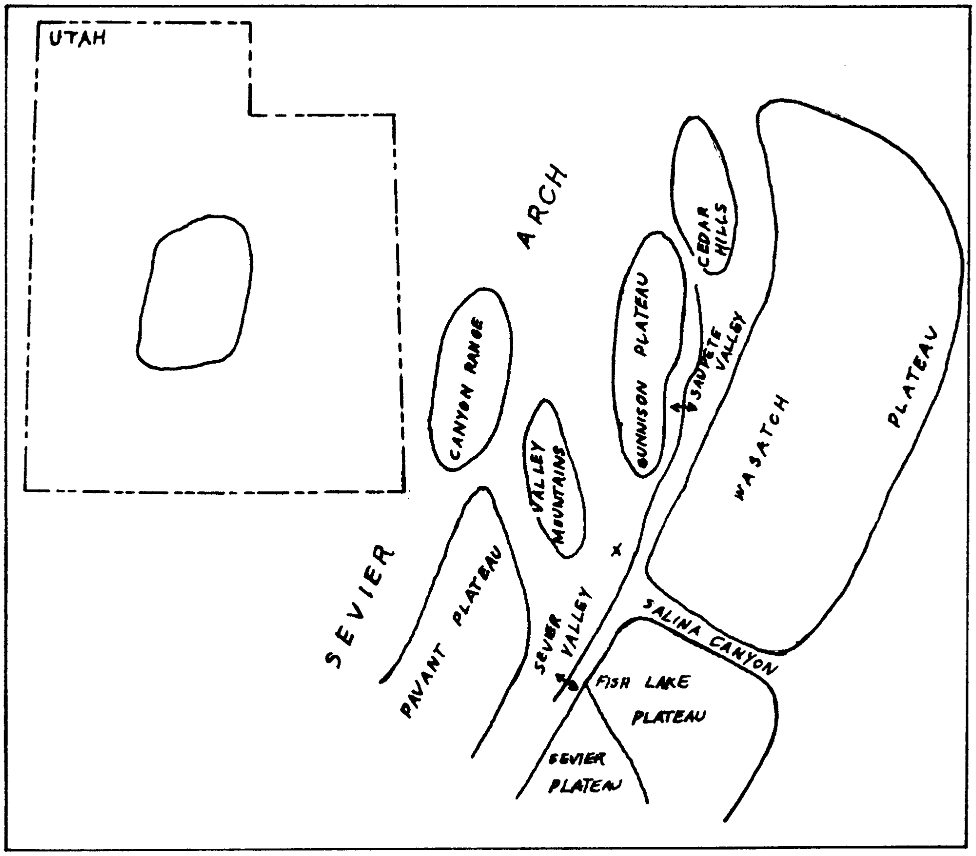


figure I

Index Map of Central Utah
Gilliland, W. N. 1963, Sanpete - Sevier Valley anticline of central Utah:
Geol. Soc. America Bull., V. 74 p. 115-124.

×Stratigraphic Sections

Figure 2--Location of stratigraphic sections with respect to communities and highways.

Portion of the State of Utah
U.S. Dept. of the Interior and U.S. Dept. of the Army
Published by the Geological Survey

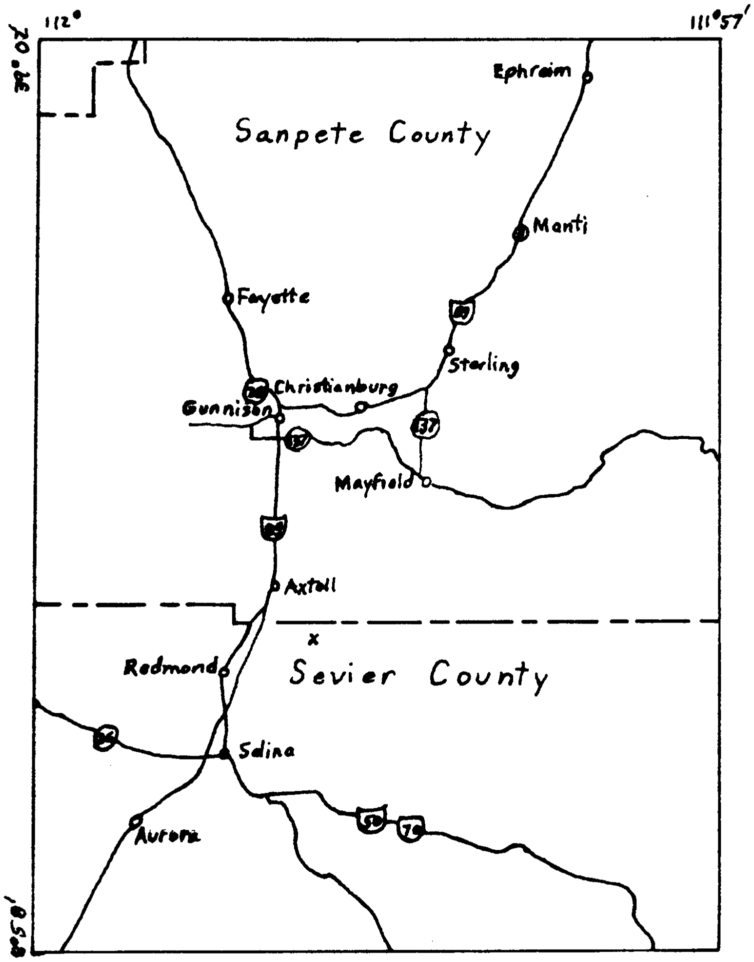


figure 2

Scale 1:500,000

0 10 20 Kilometers

LEGEND

- County Seat
- o City, town or village
- — —— County Boundary
- x Stratigraphic Sections
- Interstate highway
- U.S. highway
- State highway

Figure 3--Location of stratigraphic sections with respect to topography.

Topographic Map taken from
Redmond Quadrangle Utah
Mapped, edited, and published by the
Geological Survey

figure 3

EXPLANATION

Tc - COLTON

Tgr - GREEN RIVER

Tf - FLAGSTAFF

SANDSTONE — · — · —

ROAD CLASSIFICATION

Light duty ———

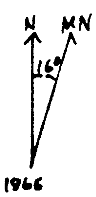
Unimproved dirt - - -

Stream —··· —···

CONTOUR INTERVAL 100 FEET

SCALE 1:24000

0 .5 1 KILOMETER



eastern margin of the Basin and Range province. The geologic features are typical of the Great Basin (Spieker 1946, p.118). The surrounding of these two ridges, consisting of Flagstaff, Colton and Green River formations, by the Arapian Shale represents typical features of the area. This area is located very near the axis of the Sanpete-Sevier Valley anticline and the town of Axtell is to the west of the axis (Figure 1). The anticline formed after deposition of the Indianola which is Cretaceous in age (Gilliland 1963, p.119). Supporting evidence for the determination of this age is the existence of the exposed core as a topographic high from the time of the early Larimide orogeny until deposition of the Green River formation and the fact that the younger part of the Flagstaff did cover the anticline as suggested by LaRocque (1960) and confirmed by Gunderson (Gilliland 1963, p.119).

Stratigraphy
Nature of the Sections

The rocks studied in the sections are early Tertiary in age. The deposits of this time and area are representative of the Great Basin. These stratigraphic sections are composed of the Flagstaff, Colton, and Green River Formations. The first measured section has at it's base the Colton and is followed by the Green River. The second section was started in the Flagstaff and includes Colton that interfingers with the Flagstaff and Green River Formation. This facies change from Flagstaff to Colton is representative of the intertongueing that persists between these two formations. The intertongueing represents the marginal-lacustrine and open lacustrine depositional environments that are illustrated by Ryder (1976), and Stanley and Collinson (1979) in their model of western Lake Unita.

Flagstaff

The base of the Flagstaff Formation in this area is interbedded red and white sandstones. Within these units are some dolomitized red mudstones. These beds are lithologically similar to the grain supported carbonate sandstones and siltstones of marginal-lacustrine origin that grade progresively basinward into open lacuestrine facies. Overlying the marginal-lacustrine beds are interbedded drab mudstones and aphanetic limestone units which represent the dark gray mud supported carbonate beds, which are probably of the open lacustrine facies of Ryder and Fouch (1976). The beds overlying these rocks are red mudstones and limestones that grade upward into a basal sandstone. This could represent a change back to a marginal-lacustrine environment.

Colton

The Colton Formation intertongues with the Flagstaff below and the Green River Formation above. The lowermost units of the Colton consist of interbedded sandstone, conglomerates and sandy and silty mudstones. These units contain red mottled materials which are alluvial in origin and are "one of the few recognized fresh water deltaic sequences of rock in the geologic record, Peterson (1976)." These are overlain by two thick units of iron stained drab mudstones with a thin layer of limestone between them. Above this is a basal sandstone sequence that is similar to the basal sandstone at the top of the Flagstaff section (Figure 4). The basal unit is characterized by large scale cross-bedding, cross-laminations, bioturbation and calcareous sandstone and mudstone units.

Green River

The Green River Formation rests on the Colton Formation in this area. It was deposited in a lake-margin carbonate-flat environment. The units in the lower part of the Green River Formation also vary systematically basinward as rated by Ryder and Fouch (1976). This section has at it's base inter-bedded gray dolomite and green and drab mudstones. Above these units representing the basinward change are dolotemized green mudstone, gray dolomite and inter-bedded drab shales with some silicified limestone. The open-lacustrine environment is characterized by gray dolomite, which is brecciated, and near the top of the section silicified. The top of the measured section is a gray limestone unit with mudstone partings and local brecciation.

Carbonate and Clay Mineralogy

Carbonate rocks in these stratigraphic sections are composed of calcite and dolomite. These minerals were identified by the use of an x-ray defractometer.

The percentage of dolomite to calcite in these rocks was also determined using the x-ray defractometer. The percentages were found on a graph by plotting the peak height ratios of dolomite to calcite versus known percentages of dolomite. Three known percentages of dolomite were obtained by measuring out 75 to 25, 50 to 50, and 25 to 75 percentages of pure dolomite, Tgr_{12} to pure calcite, F_{23}. (Appendix B). These samples were mounted and run through the x-ray defractometer to obtain the peak height ratio of dolomite to calcite and then plotted versus the known percentage of dolomite. The remaining percentages of dolomite versus calcite were found by measuring

Figure 4--Stratigraphic sections A and B from which x-ray analysis and then section samples were taken.

Stratigraphic Sections

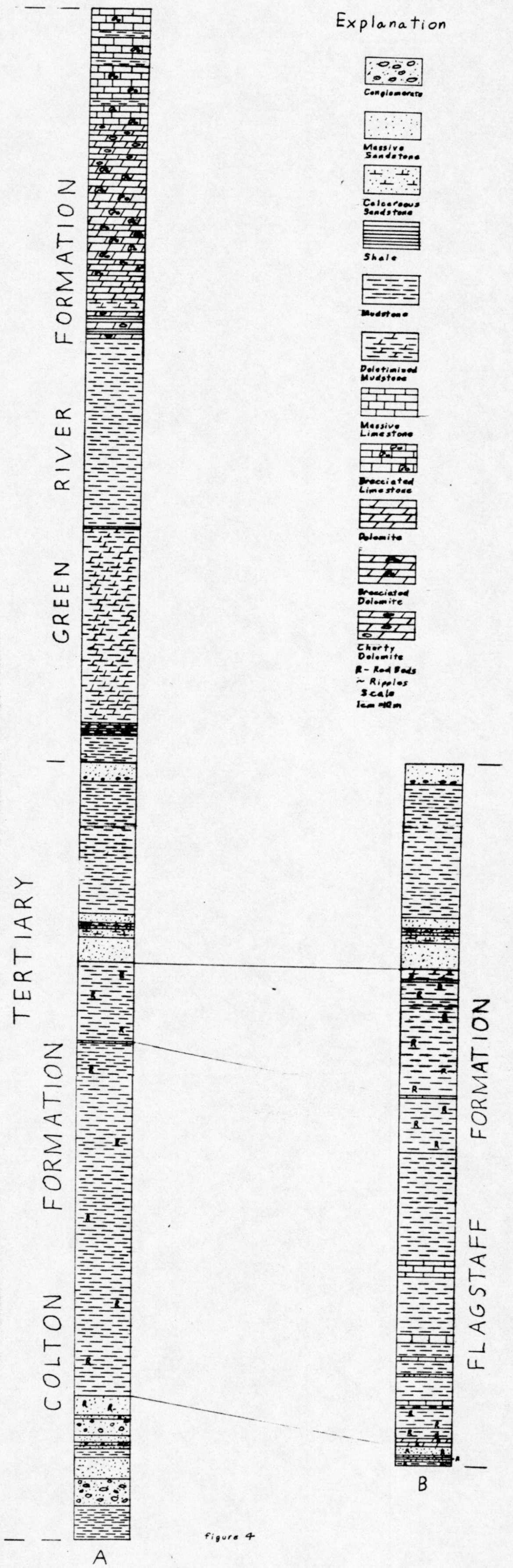


figure 4

peak height ratio and plotting them on this graph (Figure 5).

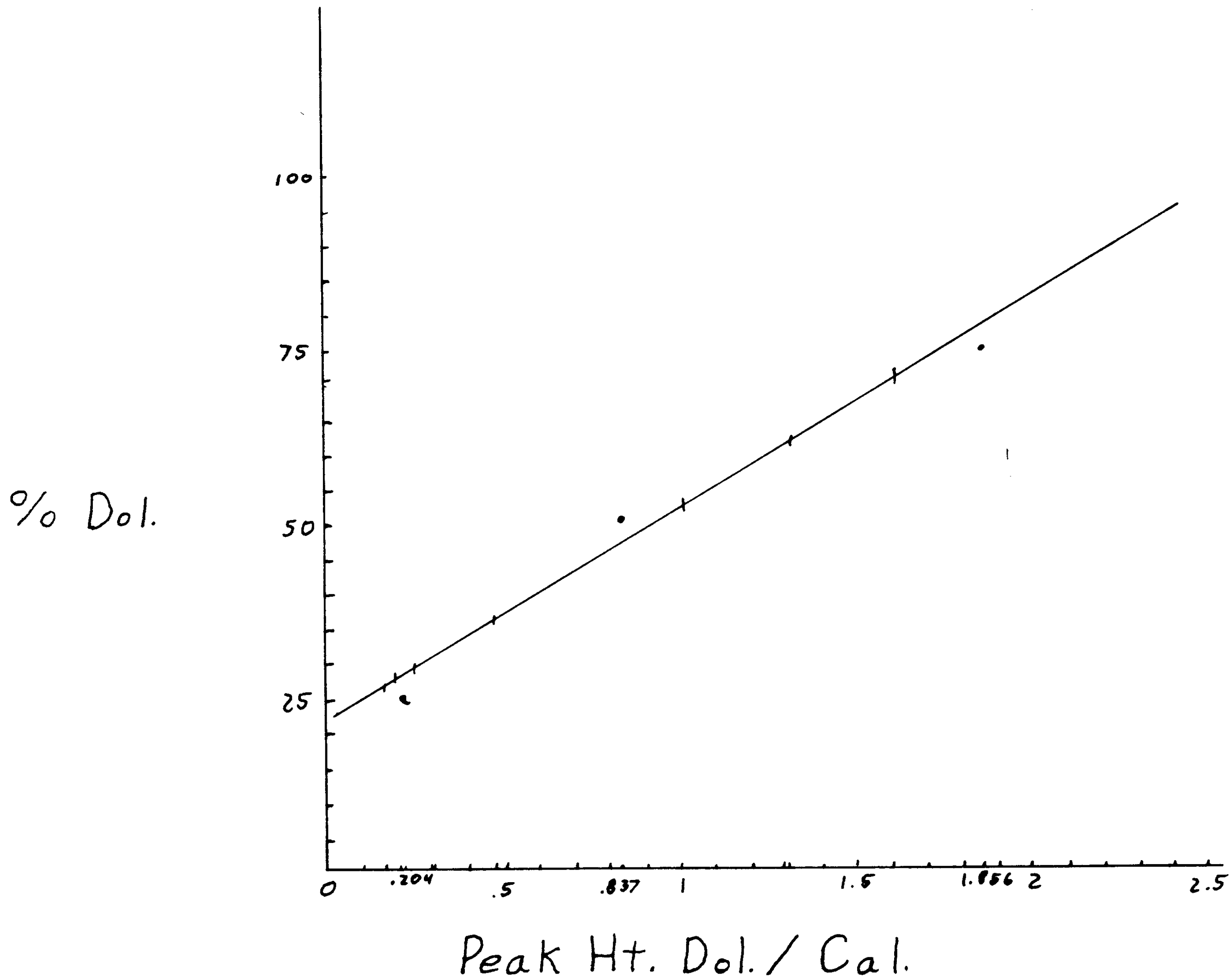
The results of this revealed that the percentage of carbonates that were dolomite was very high in the basal portion of the Flagstaff and most of the Green River. The amount of dolomite in the upper section of the Flagstaff is unknown for the most part due to the lack of samples being collected for this part of the measured section. The amount of dolomite in the Colton samples was low compared to the Flagstaff and Green River samples run through the x-ray defractometer. This is shown by the two graphs of figure six. These two graphs represent the two measured stratigraphic sections and their percentages of dolomite. The break in both graphs between the formation could represent a depositional change.

The carbonates in the thin sections were represented by micrite, dolomicrite, sparite, zeolites, clay, quartz and muscovite.

Dolomite dominates most of the carbonate rocks with a lesser amount of calcite present. The dominate form of dolomite is dolomicrite which dominates the lower part of the Green River Formation in this area. The formation of dolomicrite can be attributed to evaporative draw in the mud flat environment. This dolomicrite would be considered a chemical precipitate.

Calcite which dominates at the end of the Green River and Colton Formations is found in marginal-lacustrine and lacustrine rocks. Micrite produced biologically or under basic conditions due to evaporative draw could be the source of the micrite associated with the dolomicrite. Calcitic micrite could also be the result of abraision and breakage of calcite shells from gastropods and ostracodes or by algae on the mud flat and in the lake. The presence of algae and shell fragments in the last unit of the Green River are evidence for this.

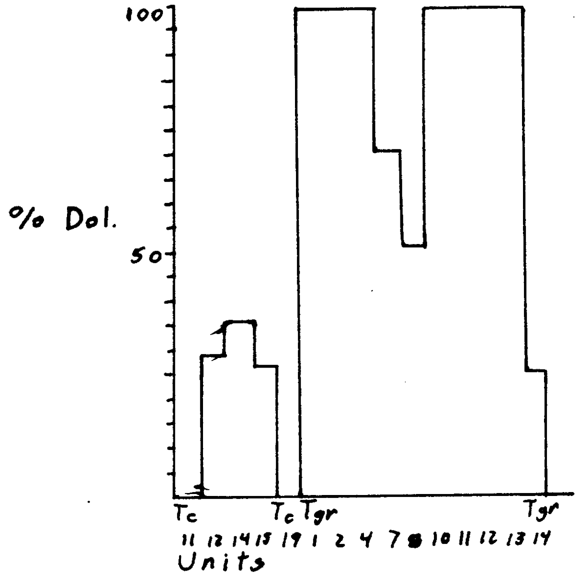
Figure 5--Graph from which percentage of dolomite was found by plotting peak height ratios.



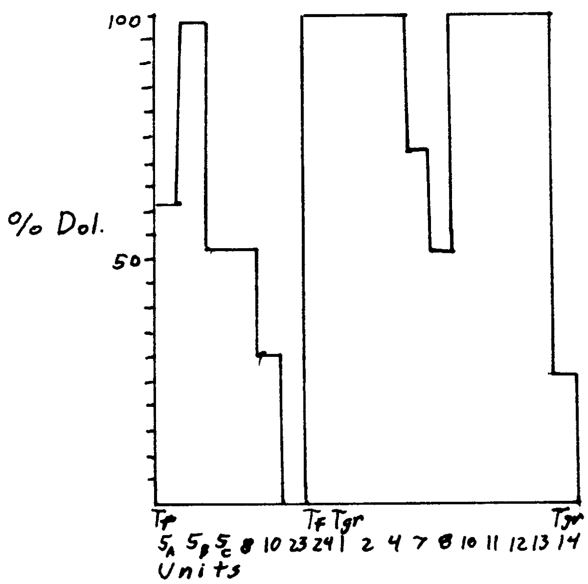
See appendix B for ratios

figure 5

Figure 6--Graph showing relationships of the amount of dolomite in each stratigraphic section.



Section A



Section B

figure 6

Sparite that is present fills in cracks and intergranular space around some grains. The Sparite can be considered secondary void filling cement. It is present only in very small amounts through the sections.

The quartz present in the carbonate units is both detrital and authigenic. The detrital quartz is more common near the base of the units. The origin of it is an extrabasinal source. The autheginic quartz is located in the dolomite units near their top and it occurs as chert replacement of carbonate.

The clay mineral in the Colton Formation is kaolinite. It was identified by using the x-ray defractometer. No clay minerals show up in the results of the x-ray samples taken of the Flagstaff and Green River Formations.

However, in the thin section study a fibrous form of zeolites was found near the middle of the Green River units. The identification of which was thought to be natrolite. A few meters above this was also some muscovite in the form of elongate irregular grains. The persence of the irregular grains are also evidence for it being extrabasinal.

Intrepretation of Depositional Environment

The depositional environment of Lake Unita in Central Utah was controlled by climate and tectonism surrounding the basin. The stratigraphic sections studied here were influenced by the changing lake level.

"The climatic conditions during the deposition of the Green River Formation in Sevier and Sanpete Counties, Central Utah are similar to those for the Mahogany Ledge in the Uinta and Piceance Creek basins of Utah and Colorado, and the Laney Member of the Bridger and Washakie basins in Wyoming" Sheliga (1980 p.118). The climate during high stands of the lake was humid and sub-tropical with high rainfall, wheras during drier periods the climate was sub-humid and sub-tropical. The evaporite facies of the Green River in the sections studied are a result of the drier period.

The green mudstones and dolomites of these sections are the result of a mudflat environment. Evidence for this is the aphanitic dolomite and micrite and the lack of sediments in these deposits. During the wetter climatic periods stream discharge would yield more sediments into these deposits. Also, during wetter periods vegetation would be heavier and rootlets, which are not present, would be preserved.

The calcite present in these facies is a result of ground water flow and evaporation. With the precipitation of calcite the amount of magnesium increased causing chemical precipitation of dolomites.

The evaporation of the lake would cause the fresh inflowing ground water to mix with a higher saline-alkaline lake water. This should promote the formation of evaporite minerals such as halite, gypsum and anhydrite. However, the absence of evaporite minerals in the sediments would be the result of dissolution. The inflowing fresh lake water during the winter would dissolve the evaporite minerals leaving no evaporite casts in the dolomite muds.

The limestone facies deposits at the end of the Flagstaff and Green River Formation took place during the wetter periods. These deposits contain shell fragments and were deposited in a lacustrine environment. During this stage the pH and salinity of the lake would be much lower allowing these deposits to take place.

Conclusions

The Green River sediments of Lake Unita in the area of study are playa-lake deposits that took place following the deposition of the deltaic Colton deposits. These carbonates were deposited during a regressive stage of the lake in mud flats or are marginal lacustrine deposits. The lack of oil shale here could be attributed to fluctuation in the lake level not taking place. If this area was to stay in a regressive phase, the high pH and high saline-alkaline conditions would persist. Evidence for this could be the lack of stevensite precipitation which takes place with a pH lower than 11.3 Sheliga (1980 p.126). Also, the only high stand deposits of the Green River in the stratigraphic sections measured was the limestone deposits at the top. A more detailed study of the high stand of Lake Unita in this area should help resolve the problem of why oil shale was not deposited here. A study of tectonics and paleogeography would also be helpful in determining what phases of the lake took place here.

Appendix A
Measured Sections, Willow Creek

Stratigraphy
Green River
Section A

Unit	Lithology of Bed	Thickness	Total
*Tgr_{14}	Limestone, gray, non-silicified 1m thick beds with mudstone partings, occasional brecciation.	42m	272
*Tgr_{13}	Dolomite, gray, brecciated and silicified.	39-55m	
*Tgr_{12}	Dolomite, gray, slight reaction with HC1.	8.5	
*Tgr_{11}	Dolomitized mudstone, green.	4.5	
*Tgr_{10}	Dolomite, gray, interbedded shales 10-60cm thick, some silicified.	4.5	
Tgr_9	Mudstone, green.	73m	
*Tgr_8	Sandstone, ripple lamenated.	.3m	
*Tgr_7	Dolimitized mudstone.	70m	
Tgr_6	Carbonate.	.5m	
Tgr_5	Mudstone.	1.3m	
*Tgr_4	Dolomite, gray drab, upper 20cm. brecciated 40cm from top silica nodules.	.9m	
Tgr_3	Mudstone green.	1m	
*Tgr_2	Dolomite, gray massive.	.5m	
*Tgr_1	Mudstone, green and drab.	10m	
	Colton		
Tc_{20}	Conglomerate, basal, large scale cross-bedding. Conglomerate pebbles 10-20cm in diameter.	.4m	282.2
	Cross-bedded material S.S.	3m	
	Burrows, ripple lamenated cross-bedded S.S.	2.5m	

Unit	Lithology of Bed	Thickness	Total
	Sandstone, massive.	.5m	
*Tc_{19}	Mudstone, red, calcified.	48m	
Tc_{18}	Sandstone, massive bioturbated.	3m	
Tc_{17}	Sandstone, ripple laminated.	1m	
Tc_{16}	Sandstone large scale cross-lamination.	1.5m	
*Tc_{15}	Sandstone, calcified, small scale cross-lamination, current ripples.	2.8m	
*Tc_{14}	Sandstone, white, matrix is clay minerals, large scale cross-bedding.	8m	
Tc_{13}	Mudstone, red.	30m	
*Tc_{12}	Limestone, micrite, bioturbation and mottling.	.5m	
*Tc_{11}	Mudstone, red.	128m	
Tc_{10}	Sandstone, some red mottled material.	7m	
Tc_{9}	Sandstone, red mottled bioturbation.	1.5m	
Tc_{8}	Conglomerate, clasts up to 30cm. in diameter.	6m	
Tc_{7}	Sandstone.	3m	
Tc_{6}	Conglomerate.	1m	
Tc_{5}	Sandstone.	1m	
Tc_{4}	Mudstone, poor.	3m	
Tc_{3}	Sandstone.	8m	
Tc_{2}	Conglomerate.	9m	
Tc_{1}	Mudstone.	13.5m	

Section B
Flagstaff

Unit	Lithology of Bed	Thickness	Total
	Basal sandstone.	70.7	251.1
*Tf_{24}	Mudstone, red, dolomite.	4.5m	
*Tf_{23}	Limestone, pure micrite with shell fragments.	.3m	
Tf_{22}	Mudstone, red.	6m	
T_{21}	Mudstone, drab.	3m	
Tf_{20}	Mudstone, red.	33m	
Tf_{19}	Limestone.	.3m	
Tf_{18}	Mudstone, red.	20m	
Tf_{17}	Mudstone, drab.	39m	
Tf_{16}	Limestone aphanitic.	6m	
Tf_{15}	Mudstone, drab.	21m	
Tf_{14}	Limestone aphanitic.	3m	
Tf_{13}	Mudstone, drab gray.	4.5m	
Tf_{12}	Limestone aphanitic.	1.5m	
Tf_{11}	Mudstone, drab.	5.3m	
*Tf_{10}	Sandstone, no biotite.	.6m	
Tf_9	Mudstone, drab.	9m	
*Tf_8	Sandstone, quartz, sub-rounded matrix is dolomictite and micr-ite.	1.5m	
Tf_7	Mudstone, drab.	1m	
Tf_6	Mudstone, redmottled.	7.5m	
Tf_{5c}	Mudstone, red quartz is sub-rounded.	10m	

Unit	Lithology of Bed	Thickness	Total
Tf_{5B}	Dolomite, red cylinders, root structures filled with red mudstone bioturbaceous.		
Tf_{5A}	Sandstone, mottled red burrowed, sub-rounded.		
Tf_4	Sandstone, white.	1m	
Tf_3	Sandstone, redmottled.	.4m	
Tf_2	Sandstone, white.	1m	
Tf_1	Mudstone, red mottled.	1m	

* Samples collected and studied.

Appendix B

X-ray Analysis

The ratio of the peak heights were obtained through the use of the x-ray defractometer. Once the ratio was found it was plotted on figure 5 to find the percentage of carbonate that is dolomite. Figure 5 was obtained from the following results of peak height and known percentages of dolomite and calcite.

			Peak Height cm
Pure dolomite	Tgr_{12}		11.67
Pure limestone	Tf_{23}		10.61
	(Peak Ht in Dol.)	(Cal. P. Ht.)	Ratio %
Tgr_{12} 50%, Tf_{23} 50%	7.04	8.41	.837
Tgr_{12} 25%, Tf_{23} 75%	2.4	11.79	.204
Tgr_{12} 75%, Tf_{23} 25%	10.6	5.71	1.856

Unit	Peak Ht. Cal. cm	Peak Ht. Dol. cm	Ratio D/C	% Dol.
Tc_{11}	1.31 cm	0.0 cm		0%
Tc_{12}	17.09	3.85	.225	29
Tc_{14}	1.52	.72	.474	36
Tc_{15}	6.88	1.29	.188	27
Tc_{19}	9.72	0.0		0%
Tgr_{1}	0.0	1.1		100
Tgr_{2}	0.0	21.1		100
Tgr_{4}	0.0	15.94		100
Tgr_{7}	3.81	6.11	1.604	71
Tgr_{8}	1.11	1.11	1.00	52
Tgr_{10}	0.0	25.22		100
Tgr_{10c_1}	0.0	19.6		100
Tgr_{10c_3}	0.0	20.05		100
Tgr_{11}	0.0	19.42		100
Tgr_{12}	0.0	23.34		100
Tgr_{13}	0.0	11.5		100
Tgr_{14}	9.26	1.45	.157	26
Tf_{5A}	2.59	3.42	1.320	62
Tf_{5B}	1.77	6.91	3.904	98
Tf_{5C}	3.4	3.64	1.071	53
Tf_{8}	3.75	3.97	1.059	53
Tf_{10}	7.09	1.7	.240	30
Tf_{23}	10.61	0.0		0
Tf_{24}	0.0	.89		100

Appendix C
Thin Section Study

Flagstaff

Tf_{5a} Sandstone, quartz 25 - 30% detrital, angular to sub-rounded, grains show undulatory extinction, grain sizes range from .05mm to .25mm. Dolomite, aphanitic, present as matrix. Calcite as Micrite in Matrix. Clay mineral, kaolinite also in matrix.

Tf_{5b} Dolomite, aphanitic texture calcite, very little present as sparite filling in around grains. Quartz 10% detrital, angular to sub-rounded size of grains range from .05mm to .33mm., undulatory extinction.

Tf_{5c} Mudstone, 30% detrital quartz angular to sub-rounded, grain size ranges from .05mm to .35mm grains show undulatory extinction.

Tf_{8} Sandstone, quartz 30%, detrital, grains range in size from .05mm to .22mm, most show undulatory extinction, grains are sub angular to sub-rounded. Matrix consists of dolomicrite and micrite. Calcite also present as sparite 1%.

Tf_{23} Limestone, 95% calcite in the form of micrite and shell fragments. Sparite fills in fractures, grains are irregular crystals and their size ranges from .15mm to .20mm.

Colton

Tc_{12} Limestone, 8-% micrite, show some bioturbation or mottling 18% dolomicrite present. 2% quartz, detrital, grains range in size from .05mm to .10mm., some show undulatory extinction, grains are sub-rounded to rounded.

Tc_{14} Sandstone, 95% detrital quartz, grain size ranges from .06mm to .33mm, grains are sub rounded to rounded, large percentage have undulatory extinction. The grains are very closely packed. Matrix consists of clay minerals, kaolinite. Carbonate present in a minute amount.

Green River

Tgr_2 Dolomite, aphanitic texture, quartz present is authigenic silica with 1% detrital quartz present.

Tgr_4 Dolomite, aphanitic texture. Quartz present is detrital and authigenic, grain size of detrital grains range from .025mm to .05mm.

Tgr_{10} Dolomite, aphanitic texture, contains some bones and shell fragments, possibly ostracodes. 2% quartz is detrital, grain sizes from .03mm to .05mm, sub angular to sub rounded quartz present also as authigenic silica.

Tgr_{10_2} Dolomite, aphanitic 98%. Zeolites are also present in a fibrous form possibly natrolite.

Tgr_{10_3} Dolomite, aphanitic texture 97%. 1% quartz detrital, grain size ranges from .04mm to .15mm, sub rounded.

Tgr_{12} Dolomite, 99% aphanitic texture, and has cloudy appearance. Muscovite, elongate irregular grains, .40mm in length and .08mm in width.

Tgr_{13} Dolomite 90%, aphanitic texture, and has some finely crystalline irregular texture. 8% quartz authigenic silica. Zeolites fibrous irregular crystal boundaries.

Tgr_{14} Limestone, 80% calcite present as micrite, 2% calcite crystals in fractures. Dolomite present in aphanitic texture. Also contains soil or algae material.

References Cited

Gilliland, W. N., 1963, Sanpete-Sevier Valley anticline of central Utah: Geol. Soc. America Bull., v.74, p.115-124.

La Rocque, A., 1960, Molluscan faunas of the Flagstaff Formation of central Utah: Geol. Soc. America Mem. 78, 100p.

Muir, M., D. Lock, and Chris Von Der Borch, 1980, The Coorong Model for Penecontemporaneous Dolomite Formation in the Middle Proterozoic McArthur Group, Northern Territory, Australia: SEPM Special Publication No. 28, p.51-67.

Peterson, A. R., 1976, Paleoenvironments of the Colton Formation. Colton, Utah: Brigham Young Univ. Geo. Studies. v.23, p.3-36.

Ryder, R. T., T. D. Fouch, and J. T. Elison, 1976, Early Tertiary sedimentation in the western Uinta basin, Utah: Geol. Soc. America Bull., v.87, p.496-512.

Scheliga, C., 1980. Sedimentology of the Eocene Green River Formation in Sevier and Sanpete Counties, Central Utah: Masters Thesis, Ohio State University.

Spieker, E. M., 1946, Late Mesozoic and early Cenozoic history of central Utah: U. S. Geol. Survey Prof. Paper 205-D, p.117-161.

1949, The transition between the Colorado Plateau and the Great Basin in central Utah: Utah Geol. Soc. Guidebook 4, 106 p.

and J. B. Reeside, 1925, Cretaceous and Tertiary formations of the Wasatch Plateau: Geol. Soc. America Bull., v.36, p.435-454.

Stanley, K. O., and J. W. Collinson, 1979, Depositional History of Paleocene-Lower Eocene Flagstaff Limestone and Coeval Rocks, Central Utah: AAPG Bull., V.63, No. 3, p.311-323.

Wolfbauer, C. A., and R. C. Surdam. 1974, Origin of nonmarine dolomite in Eocene Lake Gosiute, Green River Basin, Wyoming: Geol. Soc. America Bull., v.85, p.1735-1740.